

IX. APPENDIX I

SAMPLING AND ANALYTICAL METHOD FOR DIISOCYANATES IN AIR

The following method for sampling and analysis of airborne diisocyanates is adapted from NIOSH Method No. MR 240 (Classification E) [123]. A Class E method is defined by NIOSH as "Proposed: A new, unproven, or suggested method not previously used by industrial hygiene analysts but which gives promise of being suitable for the determination of a given substance."

Principle of the Method

A known volume of air is drawn at a flowrate of 2 liters/minute through two midjet gas impingers, connected in series, containing the nitro reagent absorber solution. The recommended airflow is 2 liters/minute, rather than 1 liter/minute as indicated in Method No. MR 240 [20], to ensure collection of particulate diisocyanates. At the time of analysis, the two impinger solutions are initially kept separate to allow determination of collection efficiency. The impinger solutions (separate or combined) are carefully rotary evaporated to dryness. The residue is then dissolved in 1.0 ml of methylene chloride, CH₂Cl₂, containing an internal standard. An aliquot of the solution is injected into a liquid chromatograph. The area of the resulting peak is determined and compared to areas obtained by injecting standard urea solutions of known concentration.

Range and Sensitivity

The upper limit of the range of the method depends on the concentration of the nitro reagent in the midjet gas impingers. For a 10-liter air sample, the limit of diisocyanates that can be absorbed is 0.0015 millimole/cu m using 15 ml of 0.2 mM nitro reagent solution.

The minimum detectable limit is 2 ng/injection for TDI and MDI and 5 ng/injection for HDI. The advisable injection volume is 50 μ l. Hence, for a 20-liter sample, the useful range is 2-300 μ g/cu m of total diisocyanates. If a particular atmosphere is suspected of containing a large amount of isocyanate, a smaller sampling volume should be taken.

Interferences

Any compound that reacts with nitro reagent and has the same retention time as the analyte is an interference. Retention time alone cannot be considered proof of chemical identity. When the possibility of interference exists,

chromatographic conditions (eg, modes of gradient, concentration of mobile phases, packings) have to be changed to circumvent the problem.

Precision and Accuracy

Precision and accuracy for the total analytical and sampling method have not been determined. However, the analytical method has been shown to have relative standard deviations within experimental error for peak areas and retention times of 2.8-16.5% and 0.6-4.1%, respectively, depending on the concentration of the analytes.

Advantages and Disadvantages of the Method

The sampling device is portable. The analytical method is specific for isocyanates, and interferences are minimal. Simultaneous analysis of five substances can be carried out routinely.

The nitro reagent must be prepared at rather frequent intervals. It is recommended that it not be stored for more than 3 weeks, and it should be kept in darkness. Commercially available nitro reagent may prove more stable. The ureas formed in solution are generally stable up to 7 days. Degradation or polymerization may occur after this period. Excess nitro reagent should be removed with p-tolyl isocyanate or by some other means before the solution is injected into the liquid chromatograph to maintain longer column life and precision.

Apparatus

- (a) An approved and calibrated personal sampling pump whose flowrate can be determined within $\pm 5\%$ at the recommended flowrate.
- (b) Two midget gas impingers connected in series, each containing 15 ml of 0.2 mM nitro reagent solution.
- (c) A liquid chromatograph capable of gradient elution and equipped with a UV detector, 254 nm.
- (d) A commercially available 25 cm Partisil 10, 4.4-mm inner diameter, stainless steel column. Other column packing material may prove to be less subject to the adverse effects of excess nitro reagent and provide equivalent or better urea separation.
- (e) A recorder or computing integrator for measuring peak areas.
- (f) Sample containers, 20-ml, with Teflon-lined caps.

(g) Microliter syringes: 10- μ l, 50- μ l, and other convenient sizes.

(h) Pipets: 1.0-ml graduated in 0.01-ml increments, 15.0-ml, and other convenient sizes for making standard solutions.

(i) Volumetric flasks: convenient sizes for making standard solutions.

Reagents

(a) Isopropanol, certified grade or reagent grade.

(b) Methylene chloride, pesticide grade (certified by ACS).

(c) Toluene, chromatographic grade.

(d) 2,4-Toluene diisocyanate, 98% pure.

(e) 2,6-Toluene diisocyanate (not available in pure form commercially; found as mixture with 2,4-TDI).

(f) 4,4'-Methylene bisphenyl isocyanate, >98% pure.

(g) 1,6-Hexane diisocyanate, 99% pure.

(h) p-Tolylisocyanate as excess nitro reagent scrubber.

(i) N-4 nitrobenzyl-N-n-propylamine-HCl (nitro reagent).

Preparation of Nitro Reagent Solution: A typical procedure for the routine preparation of the nitro reagent solution is as follows. About 120 mg (0.52 millimole) of the commercially available hydrochloride of nitro reagent is dissolved in 25 ml of distilled water. Thirteen milliliters of 1 N NaOH is added to precipitate the free amine. The free amine is extracted with 50 ml of toluene. The toluene layer is dried over anhydrous CaSO₄ (Drierite, WA Hammond Drierite Co, Xenia, Ohio), and the resulting solution is diluted to 250 ml to prepare a 2 mM solution and is stored in the refrigerator. The nitro reagent solution is further diluted 10-fold with toluene before it is added to the impinger collecting tubes. Prepared nitro reagent should be examined periodically by HPLC for the appearance of additional peaks that indicate reagent degradation.

Procedure

Until the collection efficiency of the impingers is determined adequately, the two impinger solutions for each sample must be prepared and analyzed separately. Once this information is accumulated and a consistent collection efficiency is

found, one impinger may be used and the collection-efficiency factor applied.

All glassware used should be washed with detergent and thoroughly washed with tapwater and distilled water.

(a) Collection and Shipping of Samples

The sample solution for each impinger should be transferred to a separate 20-ml glass tube with a Teflon cap. Use 1 ml of toluene to wash each impinger. Repeat twice. Combine with the appropriate sample solution. Keep cap tight and wrap with paper tapes. Ship out to place of analysis immediately. All requirements for shipping toluene, as stated in CFR 49, Part 172.101, must be adhered to.

(b) Reaction to Nitro Reagent and Isocyanate

Samples containing any aliphatic diisocyanates, such as HDI, should be allowed to react for at least 1 hour with the nitro reagent before analysis is started.

(c) Preparation of Samples

Each sample solution is transferred to a round-bottom flask. The sample tube is washed twice with 1 ml toluene and combined with the sample. The round-bottom flask is attached to a rotary evaporator and the sample is evaporated to dryness at 50 C. It is then dried over dry N₂ for 2 minutes before being redissolved into 1.0 ml of CH₂Cl₂ containing an internal standard. An aliquot is submitted to liquid chromatographic analysis.

(d) Liquid Chromatograph Conditions

Typical operating conditions for the chromatograph are:

- (1) Flowrate: 2.0 ml/minute.
- (2) Gradient elution: 10% B/A to 100% B in 10 minutes (B = 9.1% isopropanol/CH₂Cl₂; A = 100% CH₂Cl₂).
- (3) Detector: uv at 254 nm.
- (4) Temperature: ordinary room.
- (5) Recorder chart speed: 0.5 inch/minute.
- (6) Injection port: loop included.

(e) Injection

The syringe must be cleaned and dried thoroughly between injections. The syringe is then ready to take up sample for injection. A known amount of sample is injected into the liquid chromatograph. Size of injections may vary from 1 μ l up to 50 μ l.

(f) Measurement of Peak Area

The peak area is measured by peak height times peak width at half the height or by an electronic integrator such as a computing integrator. Preliminary results are read from a standard curve prepared as discussed below.

Calibration and Standards

(a) A series of standards varying in concentration over the range of interest are prepared. Calibration curves are established prior to sample analysis each day. When an internal standard is used, the analyte concentration is plotted against the area ratio of the analyte to that of the internal standard.

(b) Typical Preparation of Stock Standard Solutions.

(1) The following weights of the isocyanates are dissolved in 4.0-ml portions of CH_2Cl_2 : 2.12 mg MDI; 29.60 mg of TDI (ie, 19.30 mg of 2,4-TDI and 10.30 mg of 2,6-TDI), 21.14 mg of HDI.

(2) Then 755 μ l of MDI, 83.1 μ l of TDI, and 75.5 μ l of HDI are mixed and 1.017 ml CH_2Cl_2 is added to make a total of 2.00 ml (200 ng/liter of each). Then 1.0 ml nitro reagent (2.06 mg/ml in hexane) is added to 1.0 ml of the isocyanate mixture. The total isocyanate/nitro reagent mole ratio in this solution is 1:1. The reaction mixture is stored overnight. Dilutions are made from this solution. The solvent is evaporated in a rotary evaporator and the residue redissolved in 1 ml CH_2Cl_2 . These solutions are used to establish the calibration curves, linear dynamic range, and minimum detectable amount in the 25-cm Partisil 10 column.

Calculations

Read the weight corresponding to each peak area from the standard calibration curve.

The concentration of the analyte in the air sampled can be expressed in $\mu\text{g}/\text{cu m}$:

$$\mu\text{g}/\text{cu m} = \frac{\text{Amount of analyte } (\mu\text{g}) \times 1,000 (\mu\text{l}) \times 1,000 (\text{liters}/\text{cu m})}{\text{Air volume sampled (liters)} \times \text{volume of injection } (\mu\text{l})}$$

If more than one diisocyanate is present in the sample, the concentrations of each compound expressed in $\mu\text{g}/\text{cu m}$ can be added together to get the total concentration of diisocyanates.

Another method of expressing vapor concentration is ppb (corrected to standard conditions of 25 C and 760 mmHg):

$$\text{ppb} = \frac{\mu\text{g}}{\text{cu m}} \times \frac{24.45}{\text{MW}} \times \frac{760}{P} \times \frac{T + 273}{298}$$

where:

- P = pressure (mmHg) of air sampled
- T = temperature (C) of air sampled
- 24.45 = molar volume (liter/mol)
- MW = molecular weight
- 760 = standard pressure (mmHg)
- 298 = standard temperature (K)

However, it must be noted that concentrations expressed in ppb must be converted to $\mu\text{g}/\text{cu m}$ before being added together to obtain the combined concentration of mixed diisocyanates.

X. APPENDIX II

MATERIAL SAFETY DATA SHEET

The following items of information that are applicable to a specific product or material shall be provided in the appropriate block of the Material Safety Data Sheet (MSDS).

The product designation is inserted in the block in the upper left corner of the first page to facilitate filing and retrieval. Print in upper case letters as large as possible. It should be printed to read upright with the sheet turned sideways. The product designation is that name or code designation which appears on the label, or by which the product is sold or known by employees. The relative numerical hazard ratings and key statements are those determined by the rules in Chapter V, Part B, of the NIOSH publication, An Identification System for Occupationally Hazardous Materials. The company identification may be printed in the upper right corner if desired.

(a) Section I. Production Identification

The manufacturer's name, address, and regular and emergency telephone numbers (including area code) are inserted in the appropriate blocks of Section I. The company listed should be a source of detailed backup information on the hazards of the material(s) covered by the MSDS. The listing of suppliers or wholesale distributors is discouraged. The trade name should be the product designation or common name associated with the material. The synonyms are those commonly used for the product, especially formal chemical nomenclature. Every known chemical designation or competitor's trade name need not be listed.

(b) Section II. Hazardous Ingredients

The "materials" listed in Section II shall be those substances that are part of the hazardous product covered by the MSDS and individually meet any of the criteria defining a hazardous material. Thus, one component of a multicomponent product might be listed because of its toxicity, another component because of its flammability, while a third component could be included both for its toxicity and its reactivity. Note that a MSDS for a single component product must have the name of the material repeated in this section to avoid giving the impression that there are no hazardous ingredients.

Chemical substances should be listed according to their complete name derived from a recognized system of nomenclature. Where possible, avoid using common names and general class names such as "aromatic amine," "safety solvent," or "aliphatic hydrocarbon" when the specific name is known.

The "%" may be the approximate percentage by weight or volume (indicate basis) that each hazardous ingredient of the mixture bears to the whole mixture. This may be indicated as a range or maximum amount, ie, "10-40% vol" or "10% max wt" to avoid disclosure of trade secrets.

Toxic hazard data shall be stated in terms of concentration, mode of exposure or test, and animal used, eg, "100 ppm LC50-rat," "25 mg/kg LD50-skin-rabbit," "75 ppm LC-man," or "permissible exposure from 29 CFR 1910.1000," or, if not available, from other sources of publications such as the American Conference of Governmental Industrial Hygienists or the American National Standards Institute Inc. Flashpoint, shock sensitivity, or similar descriptive data may be used to indicate flammability, reactivity, or similar hazardous properties of the material.

(c) Section III. Physical Data

The data in Section III should be for the total mixture and should include the boiling point and melting point in degrees Fahrenheit (Celsius in parentheses); vapor pressure, in conventional millimeters of mercury (mmHg); vapor density of gas or vapor (air = 1); solubility in water, in parts/hundred parts of water by weight; specific gravity (water = 1); percent volatiles (indicated if by weight or volume) at 70 F (21.1 C); evaporation rate for liquids or sublimable solids, relative to butyl acetate; and appearance and odor. These data are useful for the control of toxic substances. Boiling point, vapor density, percent volatiles, vapor pressure, and evaporation are useful for designing proper ventilation equipment. This information is also useful for design and deployment of adequate fire and spill containment equipment. The appearance and odor may facilitate identification of substances stored in improperly marked containers, or when spilled.

(d) Section IV. Fire and Explosion Data

Section IV should contain complete fire and explosion data for the product, including flashpoint and autoignition temperature in degrees Fahrenheit (Celsius in parentheses); flammable limits, in percent by volume in air; suitable extinguishing media or materials; special firefighting procedures; and unusual fire and explosion hazard information. If the product presents no fire hazard, insert "NO FIRE HAZARD" on the line labeled "Extinguishing Media."

(e) Section V. Health Hazard Information

The "Health Hazard Data" should be a combined estimate of the hazard of the total product. This can be expressed as a TWA concentration, as a permissible exposure, or by some other indication of an acceptable standard. Other data are acceptable, such as lowest LD50 if multiple components are involved.

Under "Routes of Exposure," comments in each category should reflect the potential hazard from absorption by the route in question. Comments should indicate the severity of the effect and the basis for the statement if possible. The

basis might be animal studies, analogy with similar products, or human experiences. Comments such as "yes" or "possible" are not helpful. Typical comments might be:

Skin Contact--single short contact, no adverse effects likely; prolonged or repeated contact, possibly mild irritation.

Eye Contact--some pain and mild transient irritation; no corneal scarring.

"Emergency and First Aid Procedures" should be written in lay language and should primarily represent first-aid treatment that could be provided by paramedical personnel or individuals trained in first aid.

Information in the "Notes to Physician" section should include any special medical information which would be of assistance to an attending physician, including required or recommended preplacement and periodic medical examinations, diagnostic procedures, and medical management of overexposed employees.

(f) Section VI. Reactivity Data

The comments in Section VI relate to safe storage and handling of hazardous, unstable substances. It is particularly important to highlight instability or incompatibility to common substances or circumstances, such as water, direct sunlight, steel or copper piping, acids, alkalies, etc. "Hazardous Decomposition Products" shall include those products released under fire conditions. It must also include dangerous products produced by aging, such as peroxides in the case of some ethers. Where applicable, shelf life should also be indicated.

(g) Section VII. Spill or Leak Procedures

Detailed procedures for cleanup and disposal should be listed with emphasis on precautions to be taken to protect employees assigned to cleanup detail. Specific neutralizing chemicals or procedures should be described in detail. Disposal methods should be explicit including proper labeling of containers holding residues and ultimate disposal methods such as "sanitary landfill" or "incineration." Warnings such as "Comply with local, state, and Federal antipollution ordinances" are proper but not sufficient. Specific procedures shall be identified.

(h) Section VIII. Special Protection Information

Section VIII requires specific information. Statements such as "Yes," "No," or "If necessary" are not informative. Ventilation requirements should be specific as to type and preferred methods. Respirators shall be specified as to type and NIOSH or US Mine Safety and Health Administration approval class, ie, "Supplied air," "Organic vapor canister," etc. Protective equipment must be specified as to type and materials of construction.

(i) Section IX. Special Precautions

"Precautionary Statements" shall consist of the label statements selected for use on the container or placard. Additional information on any aspect of safety or health not covered in other sections should be inserted in Section IX. The lower block can contain references to published guides or in-house procedures for handling and storage. Department of Transportation markings and classifications and other freight, handling, or storage requirements and environmental controls can be noted.

(j) Signature and Filing

Finally, the name and address of the responsible person who completed the MSDS and the date of completion are entered. This will facilitate correction of errors and identify a source of additional information.

The MSDS shall be filed in a location readily accessible to employees exposed to the hazardous substance. The MSDS can be used as a training aid and basis for discussion during safety meetings and training of new employees. It should assist management by directing attention to the need for specific control engineering, work practices, and protective measures to ensure safe handling and use of the material. It will aid the safety and health staff in planning a safe and healthful work environment and in suggesting appropriate emergency procedures and sources of help in the event of harmful exposure of employees.

--

MATERIAL SAFETY DATA SHEET

I PRODUCT IDENTIFICATION		
MANUFACTURER'S NAME	REGULAR TELEPHONE NO. EMERGENCY TELEPHONE NO.	
ADDRESS		
TRADE NAME		
SYNONYMS		
II HAZARDOUS INGREDIENTS		
MATERIAL OR COMPONENT	%	HAZARD DATA
III PHYSICAL DATA		
BOILING POINT (760 MM HG)		MELTING POINT
SPECIFIC GRAVITY (H ₂ O=1)		VAPOR PRESSURE
VAPOR DENSITY (AIR=1)		SOLUBILITY IN H ₂ O, % BY WT
% VOLATILES BY VOL		EVAPORATION RATE (BUTYL ACETATE=1)
APPEARANCE AND ODOR		

IV FIRE AND EXPLOSION DATA				
FLASH POINT (TEST METHOD)		AUTOIGNITION TEMPERATURE		
FLAMMABLE LIMITS IN AIR, % BY VOL.		LOWER		UPPER
EXTINGUISHING MEDIA				
SPECIAL FIRE FIGHTING PROCEDURES				
UNUSUAL FIRE AND EXPLOSION HAZARD				
V HEALTH HAZARD INFORMATION				
HEALTH HAZARD DATA				
ROUTES OF EXPOSURE				
INHALATION				
SKIN CONTACT				
SKIN ABSORPTION				
EYE CONTACT				
INGESTION				
EFFECTS OF OVEREXPOSURE				
ACUTE OVEREXPOSURE				
CHRONIC OVEREXPOSURE				
EMERGENCY AND FIRST AID PROCEDURES				
EYES				
SKIN				
INHALATION				
INGESTION				
NOTES TO PHYSICIAN				

VI REACTIVITY DATA	
CONDITIONS CONTRIBUTING TO INSTABILITY	
INCOMPATIBILITY	
HAZARDOUS DECOMPOSITION PRODUCTS	
CONDITIONS CONTRIBUTING TO HAZARDOUS POLYMERIZATION	
VII SPILL OR LEAK PROCEDURES	
STEPS TO BE TAKEN IF MATERIAL IS RELEASED OR SPILLED	
NEUTRALIZING CHEMICALS	
WASTE DISPOSAL METHOD	
VIII SPECIAL PROTECTION INFORMATION	
VENTILATION REQUIREMENTS	
SPECIFIC PERSONAL PROTECTIVE EQUIPMENT	
RESPIRATORY (SPECIFY IN DETAIL)	
EYE	
GLOVES	
OTHER CLOTHING AND EQUIPMENT	

IX SPECIAL PRECAUTIONS

PRECAUTIONARY
STATEMENTS

OTHER HANDLING AND
STORAGE REQUIREMENTS

PREPARED BY _____

ADDRESS _____

DATE _____

XI. TABLES AND FIGURE

TABLE XI-1

CHEMICAL AND PHYSICAL PROPERTIES OF SELECTED DIISOCYANATES

Toluene diisocyanate (TDI)

Appearance	Colorless to pale yellow liquid
Formula	C ₉ H ₆ N ₂ O ₂
Formula weight	174.16
Boiling point	251 C (484 F) (all isomer ratios)
Melting point	20-22 C (68-72 F) (80/20% 2,4-/2,6-isomer mixture)
Vapor pressure	0.05 mmHg at 25 C (77 F) (80/20% mixture)
Specific gravity	1.22 at 25 C (77 F) (80/20% mixture)
Vapor density (air = 1)	6.0 (all isomer ratios)
Flashpoint (open cup)	135 C (275 F) (80/20% mixture)
Autoignition temperature	-
Explosive limits (% volume in air)	0.9-9.5 (2,4-isomer)
Solubility	Soluble in aromatic hydrocarbons, nitrobenzene, acetone, ethers, esters (all isomer ratios)
Conversion factors	1 µg/cu m = 0.1404 ppb 1 ppb = 7.123 µg/cu m

Diphenylmethane diisocyanate (MDI)

Appearance	White to pale yellow solid
Formula	C ₁₅ H ₁₀ N ₂ O ₂
Formula weight	250.3
Boiling point	314 C (597 F)
Melting point	38 C (100.4 F)
Vapor pressure	0.00014 mmHg at 25 C (77 F)
Specific gravity	1.23
Vapor density	8.6
Flashpoint (open cup)	196 C (385 F)
Autoignition temperature	-
Explosive limits	-
Solubility	Soluble in aromatic hydrocarbons nitrobenzene, acetone, ethers, esters
Conversion factors	1 µg/cu m = 0.098 ppb 1 ppb = 10.236 µg/cu m

TABLE XI-1 (CONTINUED)

CHEMICAL AND PHYSICAL PROPERTIES OF SELECTED DIISOCYANATES

Hexamethylene diisocyanate (HDI)

Appearance	Liquid
Formula	C ₈ H ₁₂ N ₂ O ₂
Formula weight	168.0
Boiling point	212.8 C (415 F) at 760 mmHg
Melting point	-
Vapor pressure	0.05 mmHg at 24 C (75 F)
Specific gravity	1.04
Vapor density	-
Flashpoint	140 C (284 F)
Autoignition temperature	-
Explosive limits	-
Solubility	Poorly soluble in water, readily soluble in organic solvents
Conversion factors	1 µg/cu m = 0.145 ppb 1 ppb = 6.879 µg/cu m

Naphthalene diisocyanate (NDI)

Appearance	White to yellow crystalline flakes
Formula	C ₁₂ H ₆ N ₂ O ₂
Formula weight	210
Boiling point	263 C (505 F)
Melting point	126.5-127 C (259.7-260.6 F)
Vapor pressure	0.003 mmHg at 24 C (75 F)
Specific gravity	-
Vapor density	-
Flashpoint (open cup)	155 C (311 F)
Autoignition temperature	-
Explosive limits	-
Solubility	-
Conversion factors	1 µg/cu m = 0.116 ppb 1 ppb = 8.597 µg/cu m

Isophorone diisocyanate (IPDI)

Appearance	Colorless liquid
Formula	C ₁₂ H ₁₈ N ₂ O ₂
Formula weight	222.29
Boiling point	158 C (316 F) at 10 mmHg
Melting point	Approximately -60 C (-76 F)
Vapor pressure	0.0003 mmHg at 20 C (68 F)

TABLE XI-1 (CONTINUED)

CHEMICAL AND PHYSICAL PROPERTIES OF SELECTED DIISOCYANATES

Isophorone diisocyanate (continued)

Specific gravity	1.062 g/ml at 20 C (68 F)
Vapor density	-
Flashpoint (closed cup)	155 C (311 F)
Autoignition temperature	430 C (806 F)
Explosive limits	-
Solubility	Miscible with esters, ketones, ethers, aromatic and aliphatic hydrocarbons
Conversion factors	1 $\mu\text{g}/\text{cu m}$ = 0.110 ppb 1 ppb = 9.092 $\mu\text{g}/\text{cu m}$

Dicyclohexylmethane 4,4'-diisocyanate

Appearance	Colorless to light yellow liquid
Formula	$\text{C}_{15}\text{H}_{22}\text{N}_2\text{O}_2$
Formula weight	262
Boiling point	-
Melting point	<-10 C (<-50 F)
Vapor pressure	0.4 mmHg at 150 C (238 F) 7.0 mmHg at 200 C (328 F)
Specific gravity	1.07
Vapor density	-
Flashpoint	-
Autoignition temperature	-
Explosive limits	-
Solubility	Reacts with water and ethanol; soluble in acetone
Conversion factors	1 $\mu\text{g}/\text{cu m}$ = 0.093 ppb 1 ppb = 10.753 $\mu\text{g}/\text{cu m}$

Adapted from references 1-10

TABLE XI-2

SYNONYMS FOR DIISOCYANATE COMPOUNDS AND ISOMERS

Toluene diisocyanate

TDI
Tolylene diisocyanate
Methylphenylene isocyanate
Diisocyanatotoluene
Stilbene diisocyanate
2,4-Toluene diisocyanate
2,6-Toluene diisocyanate

Diphenylmethane diisocyanate

MDI
4,4'-Diisocyanatodiphenylmethane
Methylene bisphenyl isocyanate
Methylene isocyanate
Diphenyl methane 4,4'-diisocyanate
4,4'-Methylene diphenyl isocyanate

Hexamethylene diisocyanate

HDI
HMDI
1,6-Diisocyanatohexane

Naphthalene diisocyanate

NDI
1,5-Naphthalene diisocyanate
1,5-Diisocyanatonaphthalene

Isophorone diisocyanate

IPDI
5-Isocyanato-1-(isocyanatomethyl)-1,3,3-trimethylcyclohexane

Dicyclohexylmethane 4,4'-diisocyanate

Hydrogenated MDI
4,4'-diisocyanatodicyclohexylmethane
Methylene bis(4-cyclohexyl isocyanate)

TABLE XI-3

LC50 AND LD50 VALUES OF DIISOCYANATES IN ANIMALS

Compound	Species	LC50		LD50*		Reference
		Concentration (mg/cu m)	Duration (hr)	Oral (mg/kg)	Dermal (mg/kg)	
TDI	Rats	350 (M)	4	-	-	91
		360 (F)	4	-	-	
"	"	98.7	4	-	-	101
"	"	-	-	5,800	-	36
"	"	57.7	1	3,060	-	103
"	Mice	68.9	4	-	-	101
"	Guinea pigs	90.2	4	-	-	101
"	Rabbits	-	-	-	10,000	103
MDI	Rats	369 (M)	4	-	-	91
		380 (F)	4	-	-	
HDI	"	385	6	710	-	2
"	"	310 (M)	4	-	-	91
		350 (F)	4	-	-	
"	Mice	30	2	-	-	5
"	Rabbits	-	-	-	570	2
NDI	Rats	-	-	>10,000	-	2
"	Rabbits	-	-	-	6,000	2
IPDI	Rats	260	1	>2,500	1,000	104
"	"	160 (M)	4	-	-	91
		135 (F)	4	-	-	

TABLE XI-3 (CONTINUED)

LC50 AND LD50 VALUES OF DIISOCYANATES IN ANIMALS

Compound	Species	LC50		LD50*		Reference
		Concentration (mg/cu m)	Duration (hr)	Oral (mg/kg)	Dermal (mg/kg)	
IPDI	Rats	123	4	-	-	104
"	"	33	4 (x 5 d)	-	-	104
"	Mice	-	-	>2,500	-	104
"	Cats	-	-	>1,000	-	104
Bitolylene diisocyanate	Rats	-	-	4,640	-	2
Dianisidine diisocyanate	"	-	-	>10,000	-	2
Diethylbenzene diisocyanate	"	320	6	-	-	2

*Single dose

TABLE XI-4

SKIN AND EYE IRRITATION POTENTIAL OF DIISOCYANATES IN RABBITS

Compound	Skin Irritation	Eye Injury
TDI	Moderate	Severe
MDI	Slight	Moderate
HDI	Severe	Severe
NDI	"	"
IPDI*	Moderate	"
Bitolylene diisocyanate	Slight	Slight
Dianisidene diisocyanate	None	"
Diethylbenzene diisocyanate	Severe	Severe

*From reference 104

Adapted from Woolrich [2]

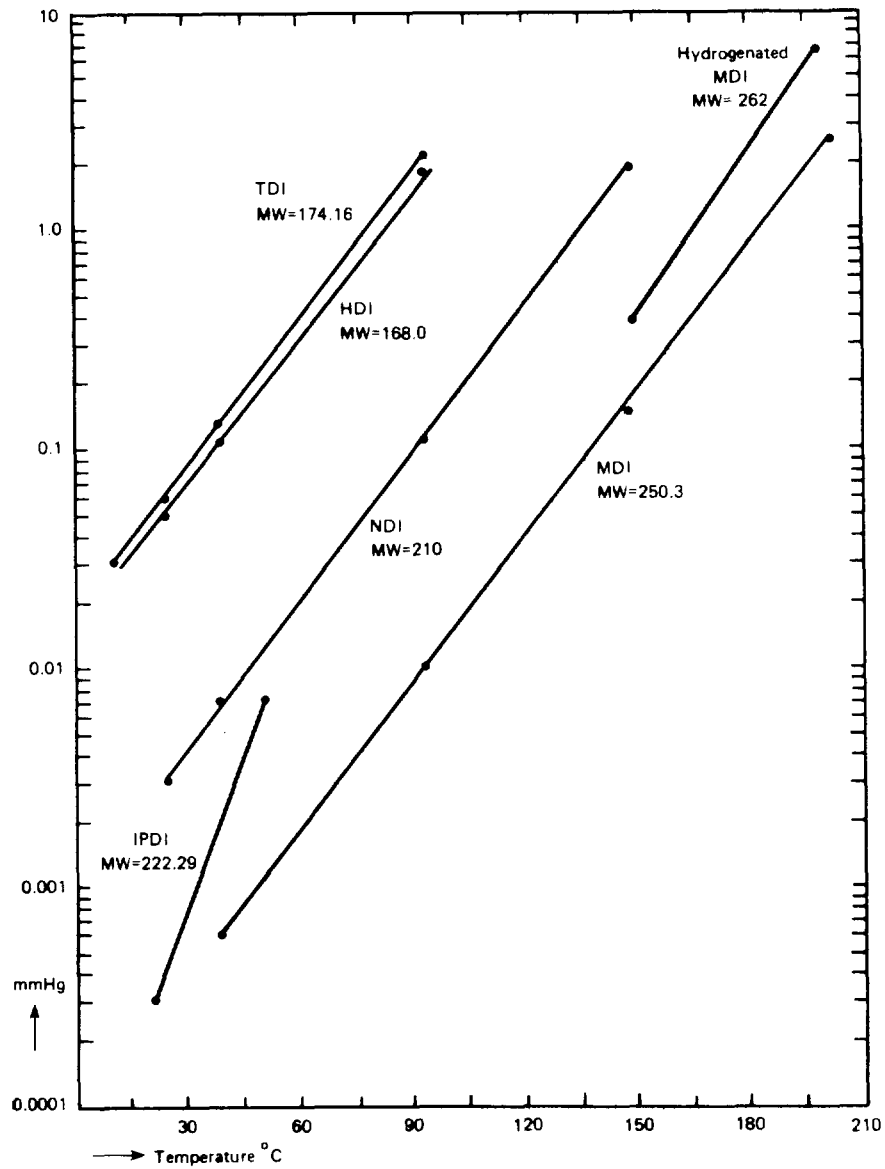


FIGURE XI-1
 VAPOR PRESSURES OF DIISOCYANATES

Adapted from references 2,6,7

DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE

PUBLIC HEALTH SERVICE

CENTER FOR DISEASE CONTROL

NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

ROBERT A. TAFT LABORATORIES

4676 COLUMBIA PARKWAY, CINCINNATI, OHIO 45226

OFFICIAL BUSINESS

PENALTY FOR PRIVATE USE \$300



POSTAGE AND FEES PAID
U.S. DEPARTMENT OF HEAL.
NEW YORK